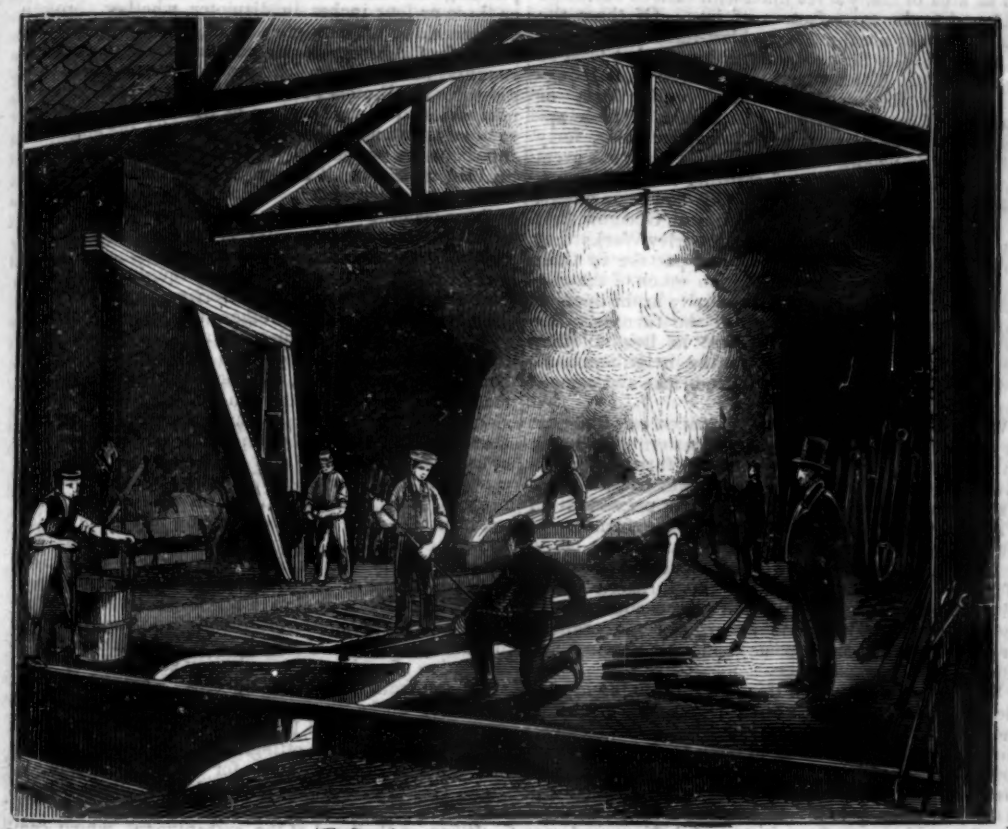
A DAY AT THE BUTTERLEY IRON-WORKS, DERBYSHIRE.



[The Foundry, or Cast-House, at the Butterley Works.]

AMONG the various manufacturing establishments which our country exhibits, there are few so important, so interesting to a stranger, and conducted on a scale of such great magnitude, as the more distinguished IRON-WORKS. Whether we go into South Wales, Shropshire, or South Staffordshire, into Derbyshire, or the West Riding of Yorkshire, or into the district of Scotland lying eastward of Glasgow, we find these smoking, fiery, ever-active works; where the precious metal iron (more precious by far than gold or silver in relation to the prosperity of a country) is extracted from the crude ore found beneath the soil. If the geological character of these districts be examined, it will be found that the iron-ore itself, and the coal which is necessary for smelting it, are found lying in beds or seams near each other; and that in some of the British mines not only may coal and iron-ore be dug out of the same pit, but they are actually combined in the same seam or bed.

The establishment, which, by the obliging permission of the proprietors, we are enabled to describe on the present occasion, is one of the most complete of its kind, and is well fitted for illustrating all the various points connected with the iron manufacture. From the mining of the crude iron-ore, extracted from the earth at a depth of five or six hundred feet below the surface, to the production of a highly finished steam-engine, every stage of the process is here conducted. Step by step is the value of the metal increased by the labour and skill bestowed upon it; and the means are afforded for seeing it in all its various states. The *Butterley Iron-Works*, to which we here allude, are situated in the eastern part of Derbyshire, near the confines of Nottinghamshire, and about four or five miles eastward of the Ambergate station on the North Midland Railway. There are in fact two works, the "Butterley" and the "Codnor Park;" but as they are intimately connected, and owned by the same Company, we here speak of them as one.

On proceeding from the Ambergate station towards the works, we pass through the village of Ripley, inhabited for the most part by persons employed at the Works in various capacities; and immediately on leaving the village the flame and smoke of the blast-furnaces point out the locality of the Iron-Works. This ever-enduring flame is one of the most remarkable features of all such works, and is in Staffordshire especially observable, from the large number of furnaces there congregated. An iron-furnace is a most untiring laboratory: it works night and day, Sunday and week-day, never stopping an instant for months, or perhaps years together; it is always nearly full of fiercely burning materials, and is replenished at the top as fast as the product is drawn out at the bottom;

and its top being generally open to the air, a vivid body of flame is almost continuously shooting upwards, visible for many miles in every direction.

When within the gates of the Butterley Works, we find an area of many acres filled with various buildings incidental to the manufacture of iron. Of these the most important are three large blast-furnaces, with all the arrangements for producing either the hot blast or the cold blast. Those who have not seen a smelting-furnace (for they are called indifferently 'blast' or 'smelting' furnaces) have but little idea of their appearance. They are huge and clumsy erections, forty or fifty feet in height, and formed so as to possess great strength and great power of resisting heat. In some instances they are conical, like a glass-house; in others, such as have recently been erected near Glasgow, they are nearly cylindrical. At the Butterley Works they have a square horizontal section, and partake in their general appearance and construction much of the character of Egyptian buildings, especially in the opening which forms the lower mouth of the furnace. The furnaces are about forty-five feet in height: they are built of stone quarried in the neighbourhood, and are lined internally with fire-bricks and cement capable of resisting heat.

When we walk round these furnaces, we find that they are all three bounded on the eastern side by an embankment nearly as high as the furnaces themselves; and on ascending this embankment by a flight of steps, the surface of the embankment presents itself as a nearly level road, terminating at the furnaces at one end, and at the mines and collieries at the other. This arrangement, as we shall hereafter explain, affords great facilities for filling the furnaces. Near this embankment is a lengthened area occupied by an enormous heap of ironstone undergoing the preparatory process of roasting; some thousands of tons being thus strewed over the place.

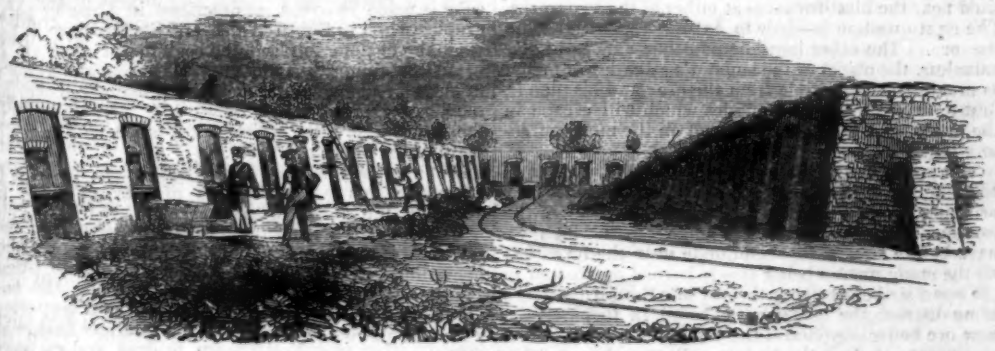
When we descend from this elevation to the level of the works, and pass round to the front of one of the furnaces, we find all the busy and remarkable arrangements for casting the melted iron into sand moulds. A very large roofed shed extends in front of the mouth of each furnace; and the floor of this shed or foundry has in it various earthen pits in which to make large castings; together with cranes for raising and shifting ponderous vessels filled with the melted iron. If these places be visited about four in the afternoon, or perhaps still more at four in the morning, at which hours the furnaces are emptied of their liquid metal, the glare of light thrown around from the mouth of the furnace, on the swarthy persons of the workmen, as well as on the dark roof and walls, together with the current of white hot liquid metal as it flows to the moulds, presents a very striking scene. If one of our distinguished painters in oil (for plain black and white cannot represent such a scene) would condescend to visit an iron-foundry at such a time, and transfer to his canvass what meets the eye, he might produce a picture in which the play of light and shade would be remarkable enough, and might at the same time convey an idea of the warm work to which furnace-men are exposed.

Beyond and around the furnaces and their foundries are various other buildings pertaining to the manufacture of pig and cast iron (the Company's wrought-iron is made not at Butterley, but at Codnor Park); and the greater part of the remainder are occupied by engineers and machine-makers. The Butterley Company, as before observed, carry on this department, as well as the manufacture of iron. In some of the lower buildings are powerful machines of various kinds for working up iron and other metal into various parts for steam-engines and other pieces of mechanism. Planing-machines, for producing a perfectly level surface on a plate of metal of any size; lathes for turning shafts, pillars, and all other articles of metal having a circular section; other lathes for cutting screws of almost every diameter and size of thread; drills for piercing holes in metal, whether an eighth of an inch or three or four inches in diameter, whether through a mere sheet or through a thick plate; boring-machines for finishing circular surfaces which have been roughly produced by casting; filing-machines, for giving to small pieces of metal the form and smoothness which are usually given by hand-files;—these are some of the various machines with which the engineering shops are provided, by whose aid the workmen are enabled to fashion all the parts of a steam-engine or other piece of apparatus. Another fine room, recently built, is occupied by pattern-makers, who form in wood exact patterns and counterparts of all the articles which are to be cast in the foundry or made by the engineers. A lofty building, of a rougher and more ponderous character, is the *erecting-shop*, where all the steam-engines and other machines made are put together in a complete form, to see that every part performs its wonted office; the cranes for lifting are of vast power, and there are other arrangements for testing the strength and fitness of the various pieces of metal. In an open space of ground between some of these buildings, the larger structures of cast-iron are put together and adjusted before being sent from the works. All the arches, suspension-bridges, roofs, and other structures now so frequently made of cast-iron, are always put up in a more or less complete form at the works of the manufacturer before delivery; and a large open space is necessarily required for this purpose. In the open area above alluded to there are railways laid down, cranes erected, and all the appliances for raising and adjusting the ponderous masses of cast-iron which enter into the formation of such structures, many such masses often weighing from ten to twenty tons. Among the engineering-works thus made and adjusted at Butterley have been—Vauxhall Bridge, a fine railway bridge at Selby, another near Nottingham, bridges and castings for the Caledonian Canal, for Dublin Harbour, for Leith Harbour, for the East and West India Docks, and others of analogous character.

When on the level of the embankment which commences near the top of the blast-furnaces, we find a line of railway extending eastward. This railway is in connection with others, branching off at various points, and in different directions; the length and number of these branches being such that there are nearly twenty miles of railway on the whole works belonging to the Company. As soon as we get beyond the precincts of the Butterley Works, we find a pleasant open country before us, dotted here and there, however, with collieries and the mouths of iron-mines. All the open district between the two works, and to a great distance on either side and beyond, are in the hands of the Company; and as the seams of coal and iron-stone extend beneath the whole district, there have been numerous pits sunk for the extraction of these valuable materials. These may, in fact, be considered as so many distinct establishments; each colliery being under a distinct manager, who has under his care several pits or shafts, a large number of steam-engines, a body of miners, and all the arrangements for conveying the produce from the Works. Each colliery or establishment of this kind has a distinct name by which it is known. One of these, for example, the "Butterley Park Colliery," being the one nearest to the Butterley Works, has twelve iron-stone pits or shafts, five coal-pits, a steam-engine of 70 horse-power, for pumping the water from the mines, and eleven other steam-engines of smaller power, for raising the

miners and the materials from the pits. All the other collieries scattered over the Company's property resemble in their general features this one. The mode of descending the shafts is very convenient and expeditious. The shafts are lined cylindrically with brick-work, and there is an iron platform which nearly fits each, and which travels from top to bottom nearly as a piston would in a cylinder. We descended one in which the platform, containing four persons, was suspended by a flat rope made of iron-wire (one of the improvements of modern times), and a steam-engine lowered us all with swiftness and regularity to the bottom, a depth of five or six hundred feet. The various galleries of the mine, extending horizontally from the bottom of the shaft, were arched passages of the usual character, but tolerably clean and free from water; and miners were there at work, cleaving and blasting the iron-ore, and the coal afterwards to be used in the manufacture of iron. The various labyrinthine passages belonging to the different collieries form a net-work, extending beneath an area of about six square miles in extent.

When on the railway above, we may proceed onward nearly in a straight line from the Butterley Works to the Codnor Park Works, a distance of about three miles, or may follow any of the branch railways right or left to the various collieries. The Cromford Canal, passing through or close by a considerable portion of the district, affords great facilities for the transfer of materials and goods. After passing the Company's canal-wharf at a spot called Golden Valley, and a brick-work, which forms part of their busy circle of operations, we pass over a bridge which has beneath it a railway laid along an inclined plane, terminating at the lower end in a wharf on the banks of the canal, and at the upper end in a very extensive coke-work belonging to the Company. This is another interesting feature in the district; for wherever there is coal fitted for making coke, a new branch of trade may be established, deriving great importance from the extensive use of coke in locomotive engines. The employment of coke in smelting iron is, as we shall explain further on, not now so general as it has been; but the Company, after supplying their own wants, have established a large sale of coke from this spot. The appearance of the coke-work is altogether singular. On ascending the inclined plane, a range of about a hundred coke-ovens is seen, lying somewhat in horse-shoe



[Coke-Ovens.]

form. Each oven is a brick structure eight or ten feet high, having a flat roof with an opening at which to introduce the coal, and another opening in front at which to remove the coke. All being arranged contiguous, there is a railway running along the roofs of all of them, at a distance of two or three feet from the charging-holes. There is a colliery close to the ovens; so that the coal is no sooner drawn up to the mouth of the pit, than it is wheeled along the railway, and emptied into any one of the ovens. In these ovens the coal is kindled without access of air, and is deprived of its bituminous and more inflammable ingredients by the usual process of coking. When the coke is removed from the ovens, and ready to be taken away from the works, it is placed in carriages on the railway, and, by an ingenious arrangement of ropes, is allowed to descend the inclined plane to the canal by its own weight, drawing up at the same time a train of empty carriages to be refilled.

These are some of the matters which come under observation on the way from Butterley to Codnor Park; and on arriving at the latter, we find that it presents a large and busily occupied area, full of smoke and bustle. Iron is made at Codnor Park, as well as at Butterley, there being three blast-furnaces at each place; but the iron is in most cases applied to a different use. At Butterley the greater part of the castings are made, as well as all the engineering; while at Codnor Park wrought-iron is the chief product. The furnaces at Codnor Park are placed on a different level from those at Butterley, with respect to the railway, insomuch that the minerals cannot be thrown into the furnace in the same way. The railway bringing the minerals from Golden Valley and from the collieries is about at mid-height of the furnace; and from this level the coal, ore, and limestone are lifted to the level of the charging-hole; in two of the instances they are raised on a platform elevated by a kind of piston moving in a cylinder; while in the other case they are propelled up a very steep inclined railway to the mouth of the furnace. Contiguous to these furnaces is an enormous pile of ironstone, containing probably twenty thousand tons, either already roasted or undergoing the process of roasting, preparatory to that of smelting.

The interior part of the works is occupied chiefly by buildings incidental to the making of wrought-iron; the nature of which we shall notice presently.

After this general glance at what we may term the topography of the various establishments forming the Works, we shall be in a condition to trace briefly the order of processes carried on therein, so far as to show the broad features of the iron manufacture. The niceties and technical difficulties of the subject will of course not be touched on here.

In the first place, then, it will be necessary to show from what iron is made, and how it is found. Is it found pure or earthy, heavy or light, moist or dry? Is it found in small pieces or in large layers, deep in the ground or near the surface? Such questions are very likely to occur, and deserve a clear answer. The metal is found combined with various earthy substances in

a stony dark-coloured ore called *ironstone*, which ore differs in different districts, some containing a larger per centage than others of pure iron, some containing clay but no lime, some lime but no clay, some holding a small quantity of coal, while others have none; but nearly all containing water, silex or flint, sulphur, and carbonic acid. The ore occurs in beds of varying thickness; some of those at Butterley are from four to five feet thick, and as the beds are generally inclined to the horizon, there are parts where they 'basset' or 'crop' out at the surface, while at other parts the bed may be many hundred feet below the surface. There are generally a great many beds or seams one beneath another, separated by beds of other mineral; and in all such cases every bed has a local name applied to it. Thus, in the Butterley Park Colliery, the several seams of ironstone receive the somewhat odd names of the 'tan-yard,' the 'cement,' the 'black,' the 'blue,' the 'old man,' the 'whetstone,' the 'wallis,' the 'nodule,' the 'stripe,' the 'kittle,' and the 'green meadow.'

We will suppose that any of these kinds of ironstone have been mined by gunpowder, brought up to the top of the pits, wheeled along the railway, and deposited near the blast-furnaces at either of the two works. The next question is—how to extract the metal from the ore. The other ingredients being almost utterly valueless, the object of the smelter's attention is to get as much iron as possible from the ore; and his plan is, first to drive off those impurities which will escape in the gaseous form, and then to act on the more refractory ingredients.

The process of *roasting* the ore is for the purpose of effecting the first of these two changes, as well as for bringing it into a state more readily acted on in the furnace. It is thus that the huge heaps which we have before alluded to, accumulate near the furnaces; all the stony masses being slowly burned or roasted in the open air before being thrown into the furnace. In some districts the roasting is effected in furnaces, the new ore being supplied at the top as fast as the roasted ore is extracted at the bottom. But we believe that at most of the larger works the roasting is effected in the open air; there is a layer of coal laid in a large level piece of ground, then a layer of ironstone in pieces of moderate size; then another layer of coal, and so on to the height of several feet, an external thatching or coat of small coal being laid over all. A fire is kindled at one end, and works its way slowly to every part of the mass, roasting the ore as it proceeds.

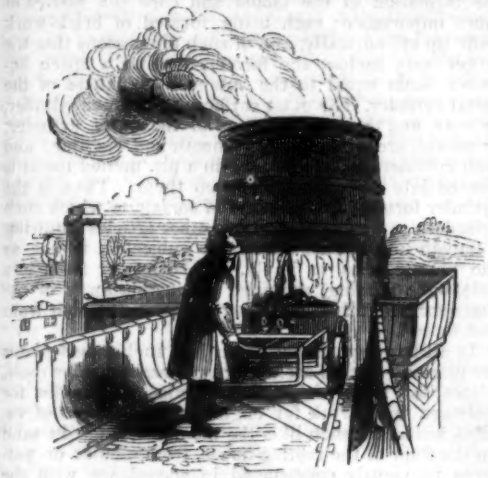
The 'raw-mine' or 'green-mine' (for the workmen apply the term 'mine' to what we have called ore or ironstone), being thus converted into 'burnt-mine,' it is ready for the blast-furnace, to have the earthen ingredients removed from it. This is done by a process which illustrates what by chemists is called 'affinity.' Lime and clay have a greater affinity for each other, or a greater tendency to combine together, than either of them with iron; and the smelter takes advantage of this circumstance to separate the metal from its accompanying impurities. If the ore be an argillaceous or clayey ironstone (which is generally the case), he adds limestone to it; if it be a calcareous or lime ironstone (which in some places occurs), he adds clay. Thus, the ironstone of the Forest of Dean in Gloucestershire contains lime, and requires clay as a flux or separator; while the ironstone of Derbyshire contains clay, and requires lime as a flux. The Butterley Company have very extensive lime-quarries westward of their iron-works, where the limestone is quarried in large blocks, and either burned into lime for sale, or conveyed by the Cromford canal to the wharf at Golden Valley, whence it is conveyed by railway either to Codnor Park or to Butterley, to be broken into smaller pieces before being introduced into the furnaces.

But something more is necessary than ore and lime; there must be fuel to generate a heat sufficient to effect the separation. This fuel is either coal or coke, and used to be charcoal. The changes from one to the other of these three kinds of fuel have marked important epochs in the history of the iron manufacture. Before the coal-mines were much used, and when our forests supplied materials for the fuel used not only for domestic purposes but in manufactures, iron was smelted with charcoal, as it is indeed at the present day in many foreign countries. Iron smelted with charcoal is, from the purity of the fuel, of very fine quality; but our national manufacture would have been almost utterly extinguished long ago, from the exhaustion of the supply of wood, had not the use of coal been introduced. The employment of coal, however, was not available in its native or raw state, since the sulphur and other foreign ingredients contained in coal would greatly injure the quality of the iron. It became necessary therefore to convert the coal into coke; and hence arose the construction of vast coking heaps or 'hearths' at iron-works. At some works the coke is made in ovens, as described in a former paragraph; while in South Wales and Staffordshire it has been the custom to place the coal in the open air, in heaps containing thirty or forty tons each, and allow it to burn in a smothered or confined manner, covering the heap externally with ashes and earth to keep in the heat—a process which adds much to the vivid glare of the district at night.

But the *hot-blast* bids fair to lessen and perhaps to supersede this wasteful mode of making coke, by affording the means of smelting with coal in its uncoked state. This most important invention we cannot well understand till after noticing the general operations of a blast-furnace, to which we will at once therefore proceed.

A blast-furnace of the usual construction has internally a square receptacle at the bottom, called the *hearth*, measuring about a yard in each direction. Above this is a cavity of varying shape, extending to the top, and in which the minerals are placed; the hearth being the receptacle for the melted iron as it flows from the ore. The proportion of the ingredients introduced varies according to circumstances; among others, by the introduction of the hot-blast. For one of the kinds of iron now making at Butterley (and which may be taken as an illustrative example), two tons thirteen hundredweight of roasted ore, two tons five hundredweight of coal, and one ton of limestone, are put into the furnace for the production of one ton of iron. The materials, as we before observed, are brought to the furnaces by railway from the pits. They are transferred to a most ingeniously constructed carriage, where there is an iron vessel suspended at one end of a long balance or steelyard, which can be so weighted as to balance with any given quantity of mineral in the vessel. The vessel is a cylinder with a loose conical bottom, apex upwards, and this bottom is capable of being lowered so far as to let the contents of the vessel escape. A given weight of coal is put into the vessel, and a man wheels along the carriage to the mouth of the furnace, which is about six feet square, and which exhibits a vast and fiercely heated body of flame from the mass of burning materials beneath. The carriage is wheeled on until the vessel passes into the furnace itself, and the man turns a handle whereby the conical bottom is lowered, and the coals precipitated in a circular stream into the furnace; after which the carriage is withdrawn, and a charge of ore and limestone similarly introduced. This mode of charging is a great improvement on the

common method, where the materials are thrown in from a hand-barrow in such a way as to fall unequally



[Filling Blast-Furnace.

in the furnace, falling to one side rather than to another.

The charges or fillings keep on uninterruptedly three or four times in an hour for day and night, never suffering further stoppage until the furnace is to be 'blown-out,' either for repairs or through depression of trade. As the mass within sinks as fast as it melts, so is the supply kept up by addition at the top, so that a furnace of such a size as those at Butterley usually contains about a hundred and twenty tons of burning materials at all times.

We next come to notice the *blast*, by which the requisite intensity of heat is maintained. So enormous is the mass of burning materials, and so great the heat required for the separation of the iron from the ore, that any of the ordinary modes of supplying air or draught would be inefficient: there must be a constant and powerful current irresistibly forced on by a powerful engine; and this current is called the blast. There are three apertures in the lower part of each furnace, on three sides of the hearth or receptacle, and in these apertures are inserted tubes called *twyeres* or *tweers*, analogous to the nose of a bellows. These twyeres are connected with a large reservoir or regulator filled with compressed air, the compressed air so stored being forced into the regulator by a powerful steam-engine, acting on the principle of a forcing-pump. If the air were forced by the engine at once into the furnace, it would produce an intermitting, irregular blast, almost powerless at one instant, and excessively strong in the next; an alternation which would greatly injure the operation of the furnace. A regulator is therefore provided (analogous to the fly-wheel of a machine), by which an equable supply of air is forced into the furnace. The blast-regulator at Butterley is an enormous cylinder of iron, thirty feet in height by nine in diameter, and therefore capable of containing nearly two thousand cubical feet of air. The success of the smelting process greatly depends on the manner in which this blast reaches the mass of burning materials, and there are various minor adjustments whereby this can be regulated. In the furnaces at Butterley the hinder end of each twyere has a hole covered with a piece of talc, through which the fire can be seen; and from the whiteness of the heat the smelter judges how the process is going on.

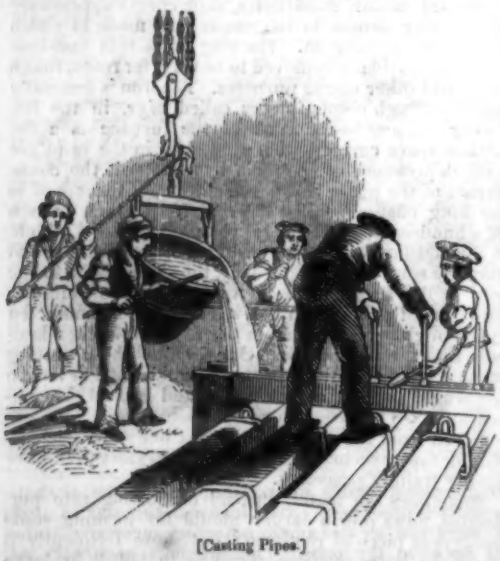
Now, it is the substitution of *hot air* for *cold air* in the above operations that constitutes the hot-blast system. The cold-blast has a tendency to chill the mass of melted materials on which it is projected, and it was long suspected that great waste of fuel resulted thereby. It remained for Mr. Neilson, however, of the Clyde Iron-Works, to introduce an efficient remedy. About fourteen years ago he took out a patent for warming the air before it was introduced into the furnace, conceiving that the quantity of fuel so expended would be amply compensated by the efficiency of that employed in the furnace itself. The invention made its way through many difficulties, and it gradually came into use throughout the iron-works of Scotland, and in many of those in England and Wales, under licence from the holders of the patent. The patent expired in the autumn of last year; and the use of this method is gradually extending, not only in this country, but on the Continent. At first the air was heated to about 300°, but as there seemed no reason why it should not produce better effects if heated yet higher, the temperature has been gradually increased to 600°, or equal to the temperature of melting lead. The principle is simply as follows:—Near the furnace is a stove-room, so arranged as to heat a series of iron pipes to any required degree of temperature. The pipes may be of any shape thought most desirable (at Butterley they have a rectangular section, measuring about nine inches by four); and the air passes through them on its way to the furnace, deriving heat (usually about 600° Fahr.) as it passes. One of the good effects of this system is, that it is found coal may be used in smelting, instead of coke, whereby a great saving is effected; and therefore in such works as those at Butterley, where coke used to be employed, coal is now used in the raw state, just as brought from the mine.

The liquid iron resulting from the action of the furnace is allowed to accumulate for twelve hours, at which time it is *tapped*, or allowed to flow out. There is a small hole at the bottom of the furnace, which is filled with clay after each tapping, and is broken open when the next tapping is necessary. In addition to this there is an opening somewhat higher, at which the scoriæ, or floating impurities, flow off from the surface of the metal: the colour, consistence, and general appearance of this *slag* denote to the smelter the mode in which the process is going on. The slag flows into cast-iron boxes, and is thence removed to be used for roads, rough walls, and other coarse purposes. The iron is generally cast into rough oblong pieces called *pigs*, in the following manner:—In front of the furnace is a flat earthen space covered with sand, and in the sand are made depressions or channels by a pattern, the counterpart of the pig. Down the middle of this space is one long channel, called the *sow*, from which branch off a hundred or more lateral channels or *pigs*, which, in the odd language of the workmen, "suck the metal from the sow." All being ready, the clay stopper to the hole in the furnace is broken away, and the white-hot liquid metal pours forth in a stream, and is conducted by a trough to the sow, from whence it branches laterally into the pig-moulds. One by one these moulds become filled with the glistening liquid, until at length the whole present a most vivid and remarkable appearance. The masses, or pigs, soon solidify, and are removed from the moulds while in a hot state; and the hole, or tap, is securely closed up preparatory to another similar train of processes.

Sometimes the metal, instead of flowing into pig-moulds, flows into a larger mould for forming some ponderous piece of cast-iron; but more frequently it is, for the latter purpose, received in ladles or large vessels, and from thence poured into moulds. We may illustrate this by noticing what came under our own view. A part of the supply of melted metal was re-

ceived in pig-moulds; while the remainder flowed into a very large iron vessel sunk in a hole in the sand. When filled, this vessel was raised by a powerful crane, swung round to another part of the foundry, where moulds for pipes had been prepared, tilted up, and the melted metal allowed to flow into the pipe-moulds. In some cases a vessel of white-hot liquid iron, weighing from one to five tons, is transferred from one crane to another, and thus conveyed to the end of the foundry, at a considerable distance from the furnace. In other cases, where more convenient, the pigs of iron are re-melted in smaller furnaces, called cupola-furnaces, and thence poured into moulds.

The mode of casting metal pipes, just alluded to, will illustrate many different varieties of iron-founding. There is formed, in the first place, a core or central pattern of cast-iron, with alternate grooves and ridges extending from end to end. Round this is wrapped a covering of hay or straw rope, and this rope is plastered with a layer of wet loam or clay, worked until the exterior surface becomes cylindrical, and corresponding in diameter with the internal dimensions of the pipe to be made. From this mode of formation it follows that there are hollow channels or gutters beneath the straw-rope, and these serve for the exit of heated air in the subsequent processes. The core, when formed, is sprinkled with powdered charcoal, and placed in a heated oven to harden. Meanwhile, the mould for giving the external form of the pipe is being prepared. A model, or pattern, is made, corresponding exactly with the exterior of the pipe to be made; and with this pattern a mould, or cavity, is formed in a smooth bed of sand, in two halves. Then, when the core is placed and supported concentrically in this mould, there is a cylindrical space between the two, equal to the thickness of the intended pipe. Holes for the admission of the melted metal, and others for the exit of the heated air, are provided, and the metal is poured in from the ladles or vessels before alluded to. It will be plain, on a little consideration, that the exterior of the core must give the interior form to the pipe, while the interior of the mould must give the exterior form to the pipe.



[Casting Pipes.]

In casting pipes of larger diameter, the core and mould are built up vertically in a pit as deep as the pipes are long; and matters are so arranged that the liquid metal is poured in at one end. In casting large cylinders for steam-engines and other purposes, the formation of the mould and core is a matter of much importance; each being formed of brick-work built up cylindrically, and of such dimensions that the larger may inclose the former, leaving a space between them equal to the intended thickness of the metal cylinder. The outer surface of the inner cylinder, or core, and the inner surface of the outer cylinder, or mould, are wrought very smooth and regular; and both cylinders being adjusted in a pit, melted metal is poured into the vacuity between them. Thus is the cylinder formed. The process of *boring*, to which such cylinders, as well as cannon and other articles requiring a smooth interior, are afterwards subjected, is not, as the name seems to imply, the boring or making a hole, but a planing, scraping, or cutting away of the inner surface, till it becomes regular and smooth from end to end.

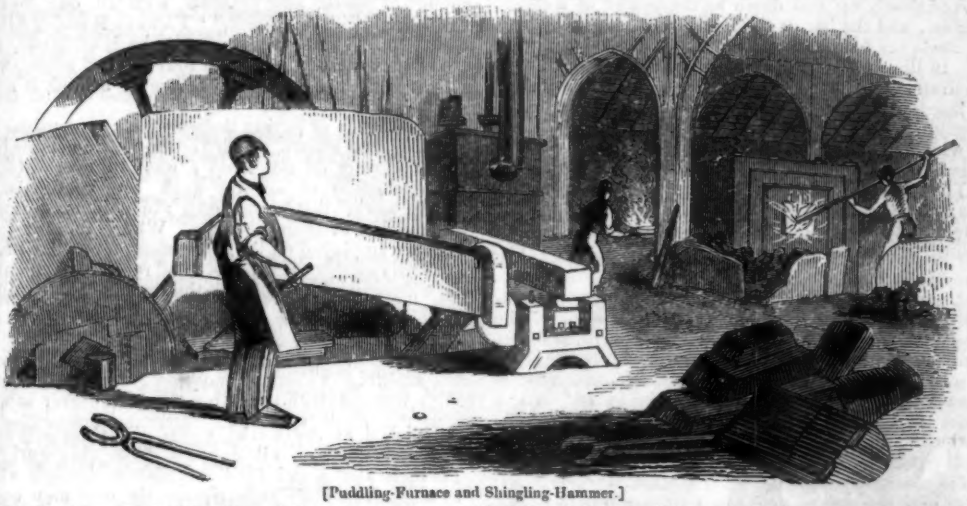
In all large specimens of casting, such as bed-plates for marine engines, arches for bridges, beams for roofs, plates for large cisterns and tanks, turn-tables for railways, framework for engines and machines of various kinds, and such like, the mould is made in sand on the floor of the casting-house, from moulds or patterns previously constructed in accordance with the working drawings, and the liquid metal is poured into these moulds at once from the blast-furnace, or from the ponderous vessels, or from a cupola-furnace, according to the circumstances of the case.

Thus far the operations belong to what is termed iron *founding* or casting, and they constitute a series full of interest, both to the intelligent inquirer as well as to the mere spectator. But the production of *wrought*-iron, involving the operations of the *forge* and the *mill*, constitutes a distinct series, at which we must next take a rapid glance.

All wrought-iron is made from 'pigs,' and is therefore equally dependent with cast-iron on the operations of the blast-furnace. The pig-iron is of various qualities, according to the purposes to which it is to be applied; and we will suppose it to be such as is fitted to make railway-bars, or sheet-iron, or any other kind of wrought-iron. The masses undergo the process of *refining* as preparatory to the other operations of the forge. The carbon and the oxygen contained in the pigs of iron appear to be necessary to the process of founding, but to interfere with the production of malleable iron; and the process of refining, as well as the next one, of *puddling*, seems intended to drive off the greater part of these ingredients. The furnace employed for refining the iron is generally a low structure, having a hearth, or bottom, of fire-bricks, and the sides of cast-iron, made hollow to allow a stream of water to pass constantly through, as a means of preventing them from being burnt away by the intense heat within. There are doors at the sides for the introduction of the metal and fuel, and a brick chimney over. The pigs of iron are placed on the hearth of a low cast-iron furnace, and covered with coke and slag; they are then exposed to an intense heat, excited by blast-pipes, until the metal becomes thoroughly melted. An aperture in the lower part of the hearth is then opened, and the white liquid metal flows into a flat mould of cast-iron, where it is almost instantly chilled by means of cold water. These long slabs of refined iron are next broken in pieces, and put into the *puddling-furnace*, where the brittle texture is exchanged for one much more malleable and ductile. The puddling-furnace is one in which the flame and heat are reverberated from an arched roof, and made to strike down on the metal. The broken fragments of refined iron are placed upon a hearth or floor, and a fire kindled by the side in such

a situation that the flame passes over an intervening bridge, and is then reflected down upon the metal. This mode of applying heat has the effect of driving off the remaining carbon and slag. As soon as the iron begins to melt, the 'puddler' watches the progress of the operation through a hole in the front of the furnace, and by means of a long bar stirs the pieces of iron, till all are equally acted on by the heat. When once the whole is melted, the puddler keeps the mass constantly stirred, changing his bars every few minutes to prevent them from melting. This operation, which exposes the workman to a great heat, is continued until the iron, by giving off an elastic fluid, becomes thickened, and separates into pasty lumps. These lumps are so turned over and combined by the puddler, by means of his rods, or bars, that he forms the whole contents of the furnace into five or six masses, called *balls* or *blooms*, averaging probably sixty or seventy pounds weight each.

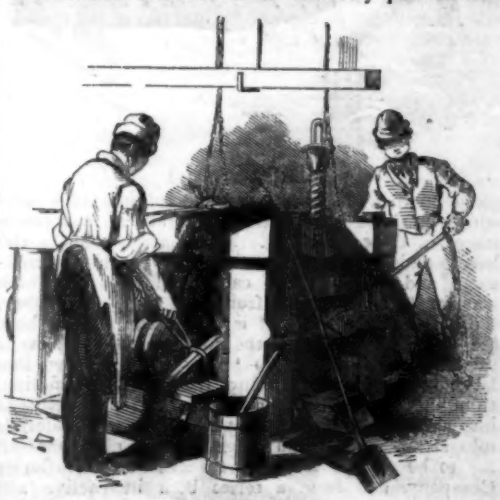
Then ensues a series of operations in which the fiery ball of iron passes from one workman to another with great rapidity, and gives a vivid and very bustling appearance to the forge-house. One of the blooms, or masses, is taken out of the puddling-furnace by means of a kind of tongs, and is quickly passed to the *shingling-hammer*. This ponderous machine, which



[Puddling-Furnace and Shingling-Hammer.]

at the Codnor Park Works weighs five tons, and requires a steam-engine of twenty horse-power to work it, is simply a hammer worked up and down several times in a minute. The bloom is placed under this hammer, and is speedily wrought into shape, the workman turning it round so that it shall receive blows on all its sides, until at length it is hammered into a square or rather oblong piece. Then, before this piece has time to cool, it is passed to the *puddle-rolls*, which consist of a pair of very large, hard, and heavy rollers working against each other, and having grooves on their surfaces. A man takes up the mass of iron, and places one end between the rollers; it is instantly seized by them while revolving, and passed between them, receiving at the same time an elongated form from the groove through which it passes. Another man behind seizes it with tongs as soon as it is protruded, and transfers it back to the first man, who passes it through a smaller groove, and so on until the iron presents the form of a rough flattish bar, two or three yards in length.

The iron is not yet in a finished or saleable state; it still retains some of its former brittleness, and has another heating process to undergo. The rough bars are cut into pieces, piled together in groups of five or six each, and placed in the *balling-furnace* (a name which will probably appear to be a very inappropriate one), shaped a good deal like the puddling-furnace. Here the bars are heated to a welding-heat, and when taken out they are passed through rollers acting in the same way as the puddle-rolls, but having grooves of a flat, square, triangular, or circular form, according to the shape to be given to the bars; or it may be that the grooves are such as will produce railway bars. By this mode of welding five or six bars together, the iron acquires a toughness and malleability which it did not before possess; and in the case of iron of very superior quality, the same process is conducted a second time. In every pair of rolls



[Rolling Bar-Iron.]

the grooves diminish in size from end to end, so that, as in the process of wire-drawing, the rod of iron becomes smaller and smaller at every successive drawing between the rolls. The two men, each with his tongs, manage the gradually elongating and still heated piece of iron, passing it to and fro, the one inserting it between the rolls, and the other seizing it

as it protrudes and passing it back to his fellow workman. Sheets of iron are made precisely in the same way, the rolls being of such a size, and having a flat surface, such as will lead to the production of a broad thin sheet, instead of a bar or rod.

The bars and sheets of iron thus produced have little more to undergo before they leave the Works. To reduce the bars to proper lengths, and the sheets to proper lengths and widths, they are subjected to the action of powerful shears, which cut the iron with a facility well calculated to astonish those who witness the process for the first time. The lower blade of each pair of shears is fixed, while the upper blade is moved slowly up and down by the power of a steam-engine; and the bar or sheet to be cut is held by hand on the lower blade, so that the upper one may act upon it. In the case of railway bars, which must fit very accurately end to end, and which must be very exact in length, this mode of cutting would not be precise enough. The bars are in this case placed on a bench, to which a gauge is attached, and the iron is cut by means of circular saws about a yard in diameter.

The business of the iron-maker here ceases. He has made bars and sheets of iron; and these now pass into the hands of others, who fashion from them the countless articles of everyday-life, from a nail to a

[Cutting Boiler-Plates.]

steam-engine. It will thus be seen that the Works which we have described exhibit all the successive stages of these processes. The quarries whence the limestone is wrought, the mines which yield the ironstone and the coal, the canal and railways which transfer these minerals from one place to another, the ovens where the coal is coked, the ridges where the ironstone is roasted, the furnaces where the ore is smelted, the casting into 'pigs,' the founding into large pieces for engineering, the refining, puddling, shingling, and rolling, whereby cast-iron is changed into wrought, and the working up of these materials into steam-engines and other finished machines—all are to be seen at the various works of the Butterley Company, and form a series both instructive and interesting.

A few words may here be added concerning what we may term the *social* or *moral* machinery of the place. Where the operations are extended over so wide an area, and partake of so varied a character, the number of persons employed must be very great. We believe that in busy times it amounts to nearly two thousand. As there are no large towns near, these workpeople form a sort of community, having not much intercourse with others, and this isolation gives to them many characteristic features. They have seldom shown a tendency to join in the outbreaks which have from time to time disturbed the manufacturing districts, and there seems to exist between the employers and the employed a kind of mutual confidence, productive of many good consequences. Nearly all the houses inhabited by the workmen belong to the Company, excepting, perhaps, those at Ripley. At the spot formerly spoken of, called Golden Valley, there is a village entirely occupied by the workmen; and nearer to Codnor Park there is another, presenting many interesting features. It is called, appropriately enough, *Ironvill*, and presents, with all due loyalty, its "King William Street," "Victoria Row," "Albert Row," &c. The houses are neatly built of brick; and are of such a character that a four-roomed house, with a neat little garden either before or behind, is let at about 4*l.* a year.

In the mode of paying the workmen, precautions are taken against abuses, which are too apt to occur where the employers do not keep a watchful eye. Most of the operations in an iron-work are conducted by "piece-work," that is, the men are paid according to the quantity of their produce. Where four or more men are employed on the same mass of iron, one man is generally master over the rest, and receives payment for the whole, giving to each man the amount of his earnings. In such a case it is required by the Company that the wages shall not be paid in a public-house, and that the payment shall be in money; the reason for the former rule is obvious, and the latter is to avoid the evils and injustice of the "truck-system." As an incentive to frugality, a Savings' Bank has been established at the works, where the Company allow four per cent. on all deposits from the workmen. There is also a sick-fund established, through which, by a small monthly subscription, the workmen ensure medical attendance, medicines, and a monthly allowance in money, when ill.

The little folks, too, are not neglected. It is a standing rule of the Company that no apprentice shall be received until he can read, write, and perform the earlier processes of arithmetic; and as this rule would press heavily on those who have not the means of acquiring education, the proprietors have built a large, commodious, and even elegant school, at Ironville, for the education of the workmen's children; and it is, we believe, in contemplation to build a church there likewise—the school being at present licensed for the Church of England service on Sundays. The school-house has two school-rooms; one for boys, and the other for girls. There are about a hundred of each sex attend the school, under the superintendence of a master and mistress, engaged expressly for the purpose. The usual and most useful branches of education are taught, and, in addition, vocal music is taught on the system of Mr. Hullah. In every large group of children there must of course be a considerable number who cannot make the least approach to correct singing; but there are in this school many who go through concerted pieces with an accuracy which would do credit to "children of larger growth;" some of them, too, being able to sing off a piece of moderately difficult music at sight. To hear a song adapted to the tune of Auber's "Prayer" in Masaniello, and such a glee as Webbe's "When winds breathe soft," sung, in three or four parts, by a little group of incipient miners or smelters—some in blue pinafores, and some in whitey-brown, and accompanied by their sisters (for both schools join occasionally in the singing-lessons)—is as novel as it is pleasant, as creditable to those who teach as it is welcome and beneficial to those who are taught.